# FUNDAMENTAL MODELING AND SIMULATION

The NASA Advanced Supercomputing (NAS) Division's fundamental modeling and simulation capability provides application code development, advances in numerical methods, and physical model enhancements for the large-scale simulations run on Agency supercomputers.

## Benefit

Fundamental modeling and simulation (M&S) capabilities are vital to NASA's long-term research and development efforts. The NAS Division's specialized tools and advanced methods are enabling better understanding of the complex physics associated with aerodynamics problems, as well as the interactions between aerodynamics, structures, propulsion, and other design disciplines that are key to aerospace vehicle performance. As the Agency's supercomputing capabilities continue to expand, increased M&S fidelity enables scientists and engineers to more accurately capture these complex interactions.

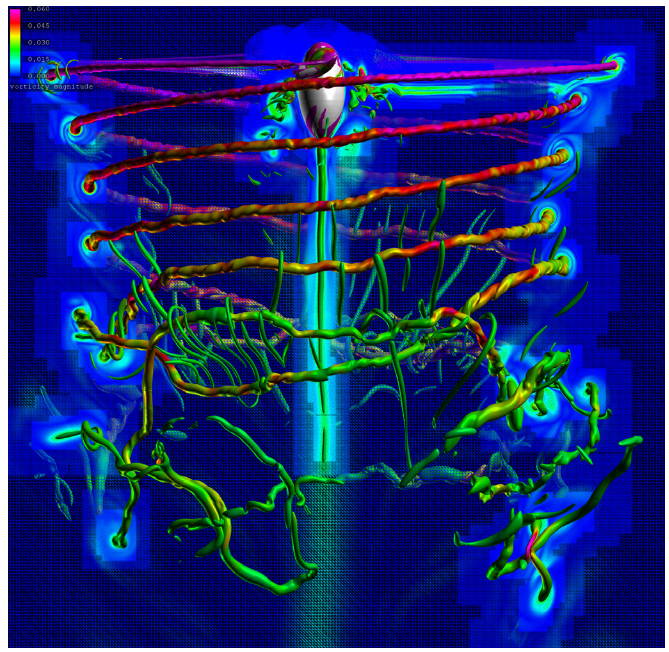
NAS computational fluid dynamics (CFD) researchers provide the modeling and simulation expertise required to analyze all flight regimes, from subsonic through hypersonic, and improve the efficiency of new designs. Applying specialized codes, and bridging any gaps with their expertise in numerical analysis, simulation science, and engineering, these CFD experts are able to respond to almost any M&S problem of relevance to NASA.

## Overview

With a focus on advancing core M&S capabilities, NAS's Fundamental Modeling and Simulation team conducts cutting-edge, long-term research to advance numerical methods, algorithms, and codes for large-scale simulations of importance to NASA, including future air and space vehicle design. This team of researchers works to improve the fidelity and usefulness of widely used computational codes such as OVERFLOW and Cart3D, which support the Agency's endeavors in aerodynamics and fluid mechanics.

They also develop new codes and algorithms to tackle fundamental physics problems and revolutionize the Agency's M&S capabilities. For example, their recently released HyperRad software tool brings a new level of accuracy to computations of the radiative effects in hypersonic flows. HyperRad is enabling better design robustness with reduced uncertainty and reduced wind tunnel and flight test costs for next-generation space vehicles, and is also proving extremely valuable to astronomers researching the chemical evolution of stars and galaxies. The Pleiades and Columbia supercomputers, operating at the NAS facility, are essential for advanced calculations required by HyperRad and other high-fidelity CFD codes.

Some key examples of how our fundamental M&S efforts are being used to make codes more useful are described below.



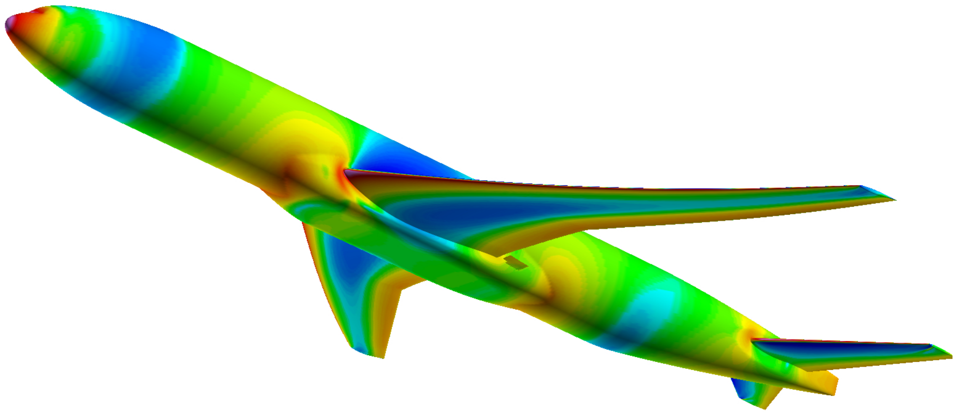

*Simulation of an isolated V-22 Osprey rotor in hover. Two levels of grid adaption improve rotor vortex resolution and predict the figure of merit within experimental accuracy. (Neal Chaderjian, Tim Sandstrom, NASA/Ames)*

## Rotorcraft Performance Improvement

NAS modeling and simulation experts are developing improved high-fidelity CFD simulation tools to help aeronautics engineers reduce noise pollution and increase performance for rotorcraft design. Using the OVERFLOW 2.2 CFD code, our M&S experts have made advances in rotor wake simulation accuracy. These techniques have reduced the vortex diameter error from 700 percent to 25 percent, and have improved prediction of key thrust and torque criteria for a hovering rotor to within 0.5 percent of the experimental value. These high-fidelity simulations provide valuable insight into the complex aeromechanics and vortex phenomena involved in rotorcraft flight.

## Efficient Aerodynamics for Transport Aircraft

As part of the NASA Subsonic Fixed Wing (SFW) Project's work to develop and analyze the NASA Common Research Model (CRM), our Fundamental M&S team, in collaboration



*Computations of surface pressure contours on NASA's Common Research Model wing/body required over 2 billion grid points, one of the most highly refined simulations ever produced. The simulation was made possible by the Pleiades supercomputer operated at NAS. (Tom Pulliam, NASA/Ames)*

with Agency and industry partners, is working to produce more accurate computations of transonic commercial aircraft. The largest computation for the CRM geometry utilized 2.4 billion grid points and is one of the largest computations of this type that has ever been performed. These results will ultimately save fuel and reduce aircraft noise and harmful emissions.

## Solar Phenomena

NAS CFD experts are developing a detailed simulation capability that more accurately predicts the solar events that affect Earth's climate, change the stability of the ozone layer, and pose risks to NASA spaceflight missions. This cutting-edge approach includes development of complex models for turbulence, non-equilibrium chemistry, and magnetic field effects, use of high-fidelity magnetohydrodynamic (MHD) simulations of sunspot active regions, and use of helioseismology, which enables reconstruction of the solar interior based on observations of solar oscillations. High-resolution simulations, with results checked against space- and ground-based observations, help scientists to understand the sources of solar variability.

## Background

The NAS Division's world-class fundamental modeling and simulation capability is built on a tradition of expertise in core research areas that include aerodynamics, aeroacoustics, advanced computational and mathematical methods, and computer science. Many of the sophisticated codes used to support critical work for the Agency, including OVERFLOW and HyperRad, were either developed or significantly enhanced at NAS. These codes continue to evolve alongside technology advances, and remain vital to NASA missions today.

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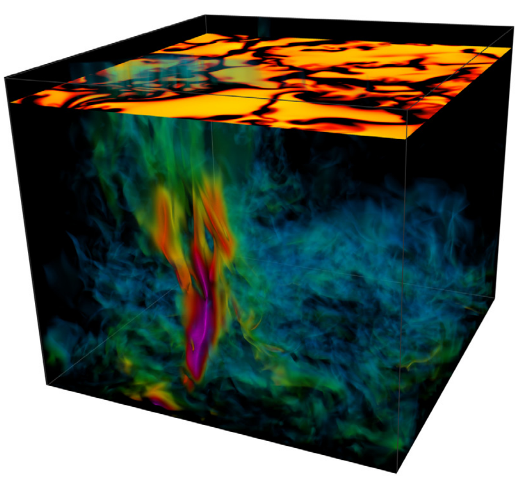

*Realistic MHD simulation showing formation of a compact magnetic structure in the Sun's upper convective boundary layer. The image shows magnetic field strength, from 1,000 gauss (black) to 6,000 gauss (magenta), and solar surface temperatures above, from 4,000 kelvin (black) to 8,000 kelvin (yellow). (Irina Kitiashvili, Stanford University; Alan Wray, Tim Sandstrom, NASA/Ames)*

*For more information on NAS Division activities, please scan the QR code below to visit: www.nas.nasa.gov*